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A FLASH X-RAY SYSTEM FOR DIAGNOSING LINEAR IMPLOSION EXPERIMENTS

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INTRODUCTION

This paper describes a low energy flash X-ray system that is ideal for radiographing a wide variety of experimental phenomenon on both capacitor-bank pulsed power facilities and explosively driven magnetic-flux compression experiments. The versatility of this system has allowed us to obtain both single X-radiographs of imploding liners and multiple, temporally resolved radiographic sequences of target evolution. The dynamic liner radiographs are acquired with radially oriented X-ray heads that are instrumental for observing and diagnosing liner shape and symmetry, Rayleigh-Taylor instability growth, and liner-glide plane interaction (see Fig. 1). Multiframe radiographs acquired along the axis of a cylindrical target are used to provide physical data on phenomena such as shock-driven target hydrodynamics, Richtmyer-Meshkov instability growth, spall, friction, and equations of state. The flexibility of this X-ray system has also allowed it to be successfully fielded both at various gas and powder gun facilities and explosively driven shock physics experiments.

INSTRUMENT DESCRIPTION

Each X-ray head is constructed with machined brass components and a nylon insulator. The field emission cathode is a brass collar that is tapped with machine bolt threads and varies in inner diameter from 3 to 7 mm. Typical anodes are 1.5 mm diameter tungsten rods that are tapered to a needle-like point, but molybdenum or copper may be used for experiments where a softer X-ray spectrum is desired. Anode size may also be changed from 0.5 mm to 3 mm in diameter depending on the spot size and anode lifetime required. The measured source spot size is primarily determined by the anode rod diameter as shown in Figure 2. Anode lifetimes vary from 2 to 60 shots, depending on diameter, and are easily replaced. All other X-ray head hardware is reusable after careful cleaning and minor refurbishing.

A key feature of the X-ray system is its compact size and the ability to package the X-ray heads in a variety of different configurations. This allows it to be fielded in challenging experimental geometries where space and diagnostic access are limited. Once constructed, each head is inserted into a stacking frame assembly that determines the arrangement of the system. A multi-head package that shares a nearly identical line of sight or a linear array of several sources with anode separations of 6-12 mm are two of the possible configurations (See Figure 3).

The Marx driver for this system is a small, self-contained, portable unit that is conducive to use in cramped and electrically hostile environments. The Marx is housed in a EMI shield with fiber optics used for switching, monitoring, and triggering to make it insensitive to most electrical noise (See Fig. 4). Power is provided via a small, +27 volt battery pack that has a lifetime of several-hundred shots. This allows the Marx to be floated or single-point grounded and virtually eliminates prefire and pretrigger situations. The high-voltage section of the Marx is pressurized to ~90 psi, and the source connector is pressurized with a minimum of 60 psi of clean dry air. This is a 25-stage Marx, with each stage consisting of 2 parallel, 40-kV, 2.7 nF capacitors. The capacitor pairs are charged with +36 kV to a total stored energy of 87.5 J and a fully erected open circuit voltage of +900 kV.

Each Marx bank is cable coupled to an individual X-ray head with as much as 20 meters of RG-220 (50 ohm) cable without any degradation of measurable dose levels. This remote coupling arrangement allows for protection of the Marx even in harsh experimental situations, such as explosively driven generators, and yet permits the X-ray head to be situated as close to the radiographic object as desired while limiting the amount of damage to expensive equipment.

When the Marx fires, each source receives an approximately 26 ns wide, +350 kV pulse across the A-K gap in the X-ray head and generates a dose of 250-350 mR at 30 cm. The X-ray spectrum is composed primarily of broad band Bremsstrahlung radiation with an endpoint energy of ~350 keV and K_α line radiation determined by the anode material. As shown in Fig. 5, the dose and X-ray pulse width is quite consistent from shot-to-shot until the anode becomes significantly eroded away (typically 15-20 shots for a 1.5 mm diameter tungsten anode).

CONCLUSION

This system is a dependable low-energy flash x-ray source for obtaining a sequence of temporally resolved X-radiographs of pulse power and explosively driven magnetic-flux-compression experiments. The flexibility to radially orient the sources to investigate liner shape and implosion symmetry or to axially orient them for image shock-driven target hydrodynamics has proven invaluable. This very robust, yet compact and adaptable system allows it to be used in a wide range of applications.

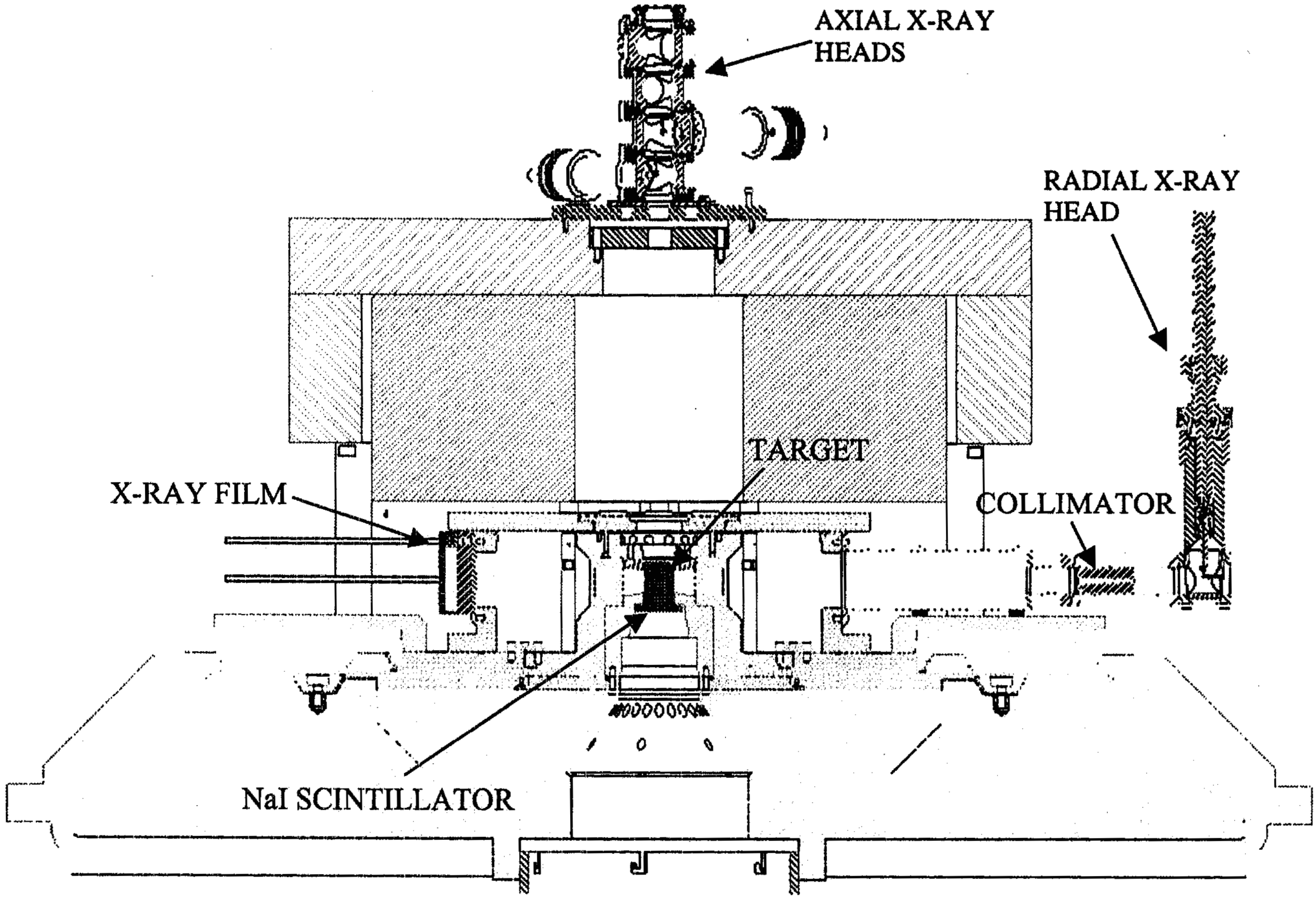

Figure 1. Axial and radial X-ray head arrangement on the Atlas pulsed power capacitor bank.

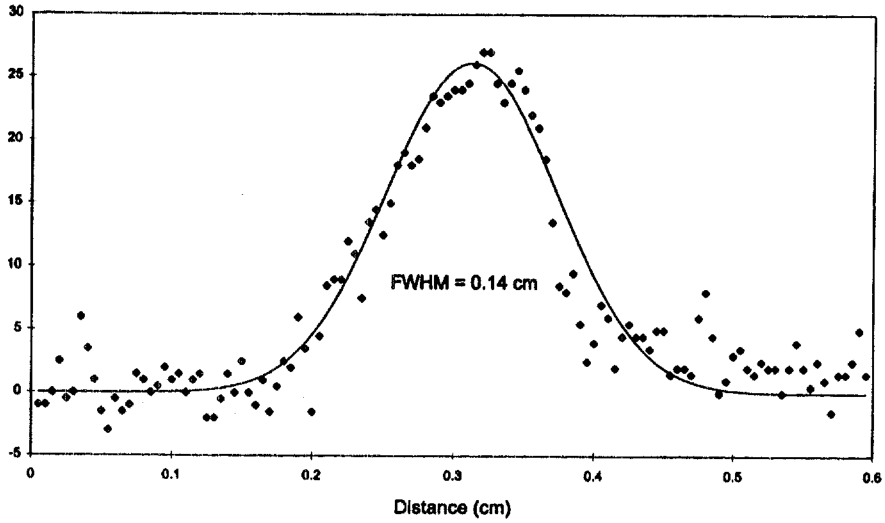

Figure 2. X-ray spot size measurement for a 1.5 mm diameter anode.

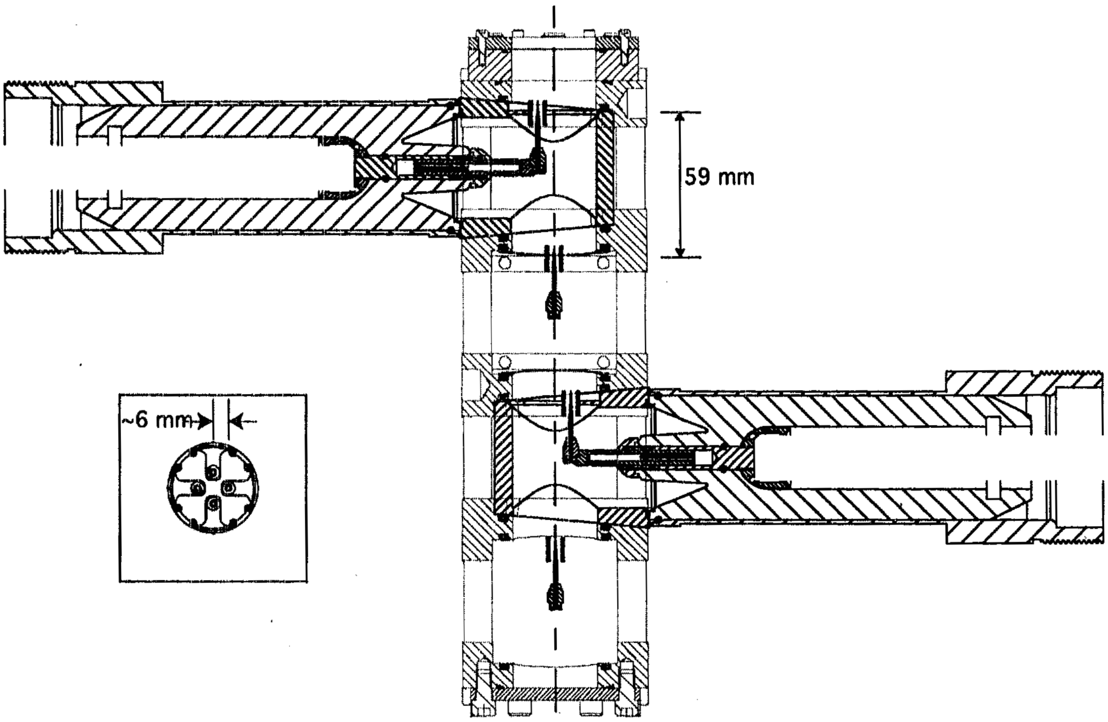

Figure 3. A four X-ray head arrangement with each head sharing a nearly identical line of sight. Each anode is 6 mm from the axis of the X-ray head stack.

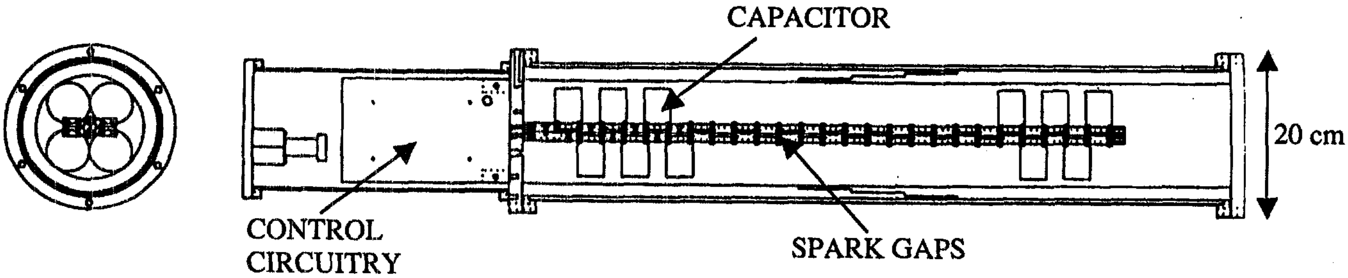

Figure 4. Schematic drawing of the 900 kV Marx bank driver for the X-ray heads.

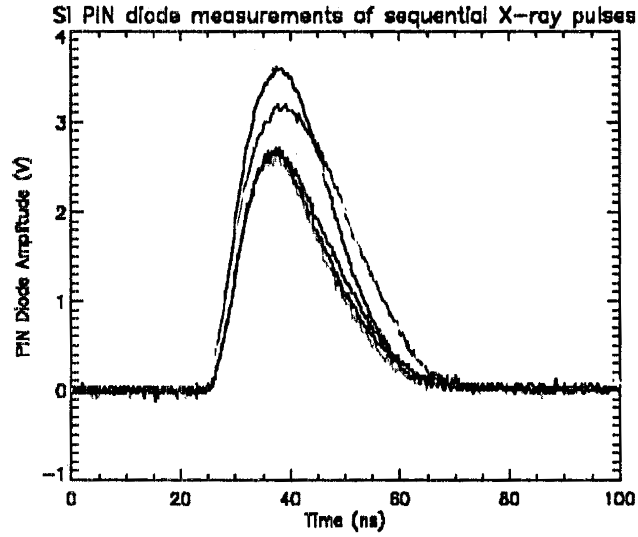

Figure 5. Si PIN diode measurements of ten sequential shots from a X-ray head with a new 1.5 mm tungsten anode.